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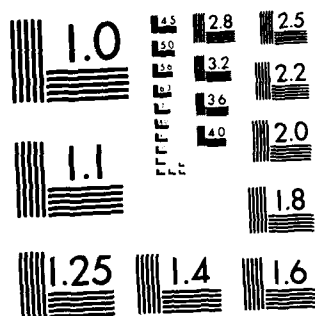
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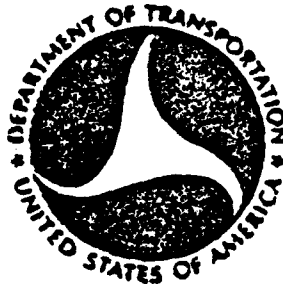


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LONG-TERM MOVEMENT OF SATELLITE-TRACKED BUOYS IN  
THE BEAUFORT SEA - AN INTERIM REPORT

D.L. MURPHY, P.A. TEBEAU, and I.M. LISSAUER  
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Avery Point Groton, Connecticut 06340



June 1981

Interim Report

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16. Abstract  <p>Trajectories of five free-drifting satellite-tracked buoys released during the summer of 1979 in open water in the Beaufort Sea north of the Tuktoyaktuk Peninsula indicate a pronounced east-to-west near-surface flow along the northern Alaskan coast. The direction of the buoy movement is in general agreement with the direction of the flow in the southern portion of the Beaufort Sea Gyre as previously calculated from dynamic topography.</p> <p>The buoy tracks and speeds differ from the surface circulation calculated from the dynamic topography in two respects. First, the average buoy speeds (<math>\sim 20</math> cm/s) were approximately 3 times larger than calculated surface currents. Second, three of the buoys moved onto the Chukchi Sea shelf near Wrangel Island instead of turning to the northwest near Point Barrow with the Beaufort Sea Gyre. The remaining two buoys stopped transmitting before reaching Point Barrow.</p> <p>Analysis of the available wind data suggests that the surface currents as indicated by the motions of the buoys were strongly influenced by the local wind. For surface wind speeds, <math>\geq 5 \text{ ms}^{-1}</math>, the buoys moved <math>22^\circ</math> to the right of the wind at 3.8% of the wind speed.</p>			
17. Key Words  surface currents, drift speed, Beaufort Sea, satellite-tracked buoys, wind-driven circulation		18. Distribution Statement  This document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161	
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# METRIC CONVERSION FACTORS

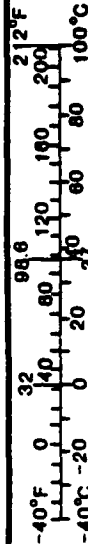
## Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
<b>LENGTH</b>				
in	inches	* 2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
<b>AREA</b>				
in <sup>2</sup>	square inches	6.5	square centimeters	cm <sup>2</sup>
ft <sup>2</sup>	square feet	0.09	square meters	m <sup>2</sup>
yd <sup>2</sup>	square yards	0.8	square meters	m <sup>2</sup>
mi <sup>2</sup>	square miles	2.6	square kilometers	km <sup>2</sup>
	acres	0.4	hectares	ha
<b>MASS (WEIGHT)</b>				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
<b>VOLUME</b>				
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft <sup>3</sup>	cubic feet	0.03	cubic meters	m <sup>3</sup>
yd <sup>3</sup>	cubic yards	0.76	cubic meters	m <sup>3</sup>
<b>TEMPERATURE (EXACT)</b>				
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

\* 1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Mac. Publ. 266, Units of Weights and Measures. Price \$2.25.  
SD Catalog No. C13.10.286.

## Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
<b>LENGTH</b>				
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
<b>AREA</b>				
cm <sup>2</sup>	square centimeters	0.16	square inches	in <sup>2</sup>
m <sup>2</sup>	square meters	1.2	square yards	yd <sup>2</sup>
km <sup>2</sup>	square kilometers	0.4	square miles	mi <sup>2</sup>
ha	hectares (10,000 m <sup>2</sup> )	2.5	acres	
<b>MASS (WEIGHT)</b>				
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
<b>VOLUME</b>				
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m <sup>3</sup>	cubic meters	35	cubic feet	ft <sup>3</sup>
m <sup>3</sup>	cubic meters	1.3	cubic yards	yd <sup>3</sup>
<b>TEMPERATURE (EXACT)</b>				
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



# ACKNOWLEDGEMENTS

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## 1.0 INTRODUCTION

Efforts to predict the movement of oil spilled into the marine environment are often frustrated by a lack of adequate oceanographic data. This is particularly true in the Beaufort Sea (figure 1), an area of active oil exploration in both Alaskan and Canadian areas, where little is known about the circulation patterns. In addition, the region is ice-covered for much of the year and, even during open water in the summer months, the proximity of the ice edge and floating ice will complicate efforts to predict the movement of an oil spill.

This report describes the first-year results of a study of the circulation in the southern Beaufort Sea using free-drifting satellite-tracked buoys. The primary emphasis of this report is on the description of the near-surface flow during open water conditions in 1979. To examine year-to-year variability, additional buoys were released in 1980 and will be released again in 1981. The results of these more recent efforts will be the subject of a future report.

During the 1979 drift experiment, seven buoys were released in the eastern portion of the Beaufort Sea. Comparison was made between the buoy trajectories and the mean surface flow of the Beaufort Sea Gyre to determine whether the geostrophic current dominates the circulation. In addition, the buoy trajectories were compared with available wind data to evaluate the role of the wind in driving the surface currents.

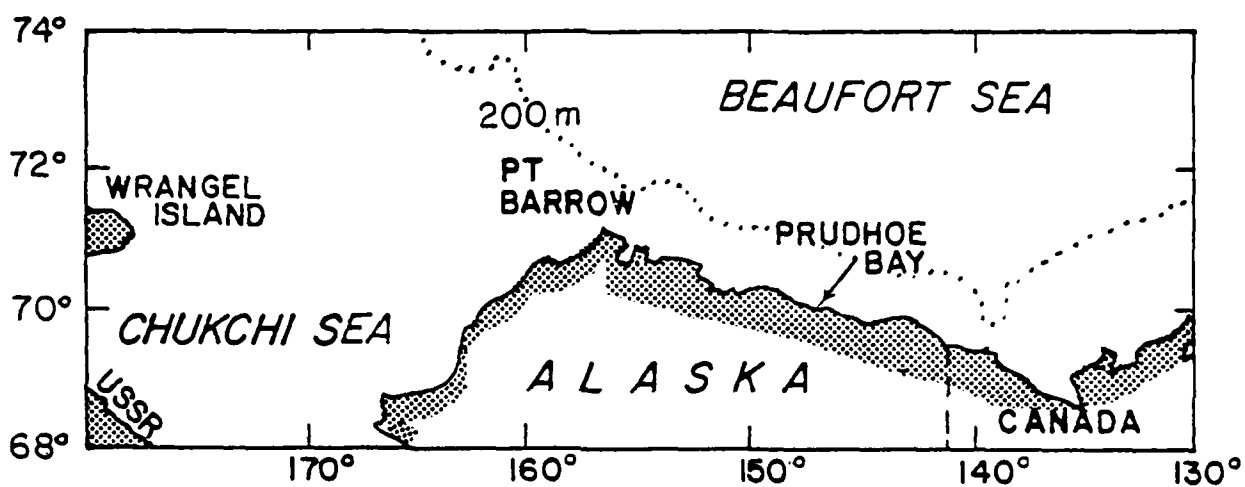


FIGURE 1

Area of Study - Beaufort Sea

## 2.0 DATA ACQUISITION

### 2.1 Buoy Positions

#### 2.1.1 Buoy Description

Two buoy types, with slightly different hull designs, were employed in this study. The large hull (figure 2) consists of a 38.1 cm diameter cylinder while the small hull's diameter (figure 3) is 20.0 cm. Another difference is that the small hull was fitted with a 76 cm diameter float collar. The two hulls were approximately the same length and for both the ratio of the submerged area to exposed area was nearly 2:1. None of the buoys had drogues.

In the present study, the buoy movements are assumed to be representative of the near-surface flow, that is, the flow in the top two meters of the water column. This assumption is made recognizing the fact that, because the buoys float with a significant portion above the sea surface, wind stress acting on the exposed portion of the hull causes a downwind movement which contaminates the movement caused by the surface current. Several factors support the use of this simplifying assumption. First, a previous attempt to correct the buoy movement by eliminating direct wind effects (Kirwan, et al., 1978) resulted in unrealistically high corrections. The authors concluded that the uncorrected records were a better representation of the ocean currents. Second, in a recent study McNally (1981), using the same buoy hulls employed in the present study, showed that there was no significant systematic difference in the movement of drifters without drogues and those with drogues at 30 meters in the equatorial Pacific. This finding also suggests that direct wind effects on the exposed portion of the buoy do not dominate the buoy motion. Finally, Mountain et al. (1980) used an undrogued buoy (with a slightly different hull design but with approximately the same dimensions) to track a patch of oil during the IXTOC I spill and found that the buoy was closely associated with the patch after approximately two weeks and 300 km of drift. This final argument is especially significant because the ultimate intent of the present effort is to estimate the movement of spilled oil.

The buoys were tracked remotely by the Random Access Measurement System (RAMS) on board the NIMBUS 6 satellite. The platform positions are determined by Doppler shifts in the buoy transmissions during the satellite pass; Kirwan et al. (1976) provide a summary of the RAMS. The advertised position accuracy of the RAMS is +5 km. This is probably a conservative estimate; for example, Robe et al. (1980) found the position uncertainty to be +3.52 km in the Labrador Sea and Baffin Bay.

#### 2.1.2 Preliminary Data Processing

In processing the raw data, two criteria were used to eliminate bad positions from the data file. The first was based on the NASA provided quality factor, a statistical index that indicates what confidence can be placed in a given position. Because the results of this test were not always conclusive, it was necessary to examine the raw buoy trajectories and calculated velocities for further evidence of faulty positions. Data points which resulted in erratic behavior, such as rapid 180° shifts in direction

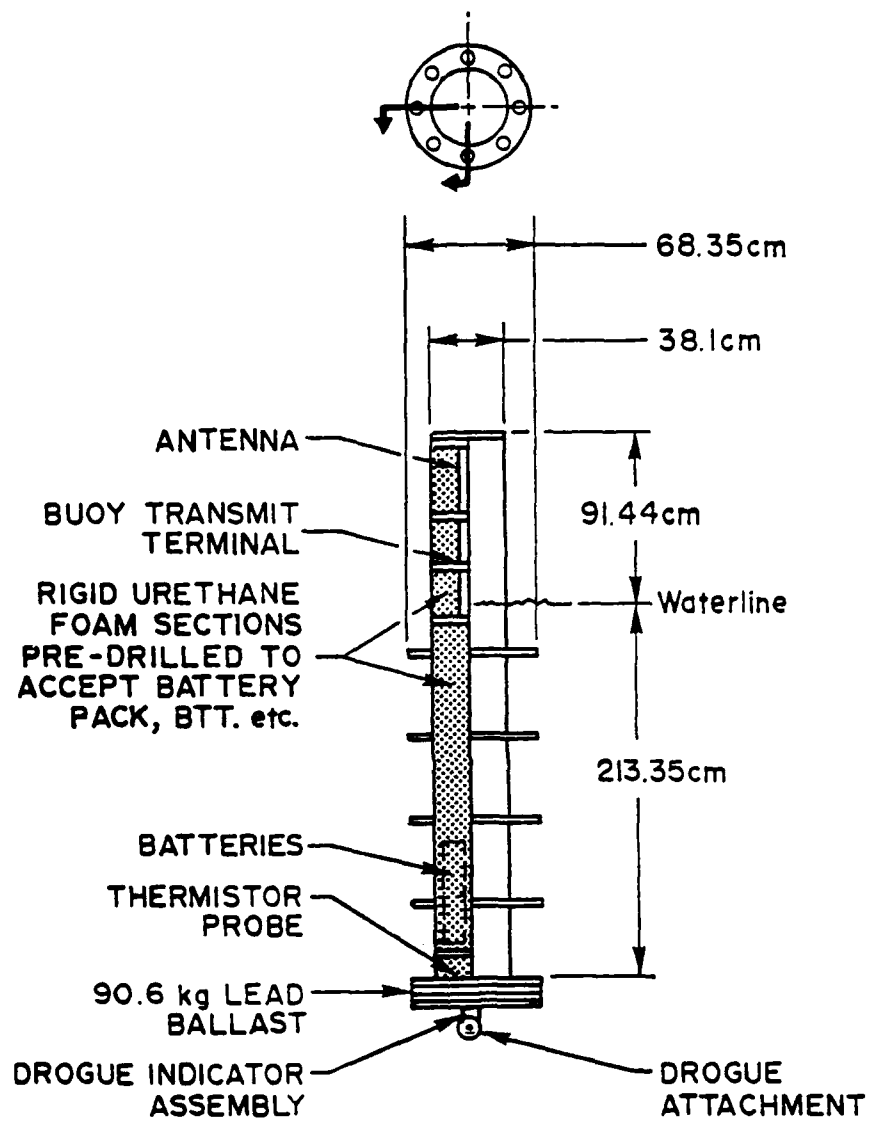


FIGURE 2

Large Buoy Hull Used in this Study

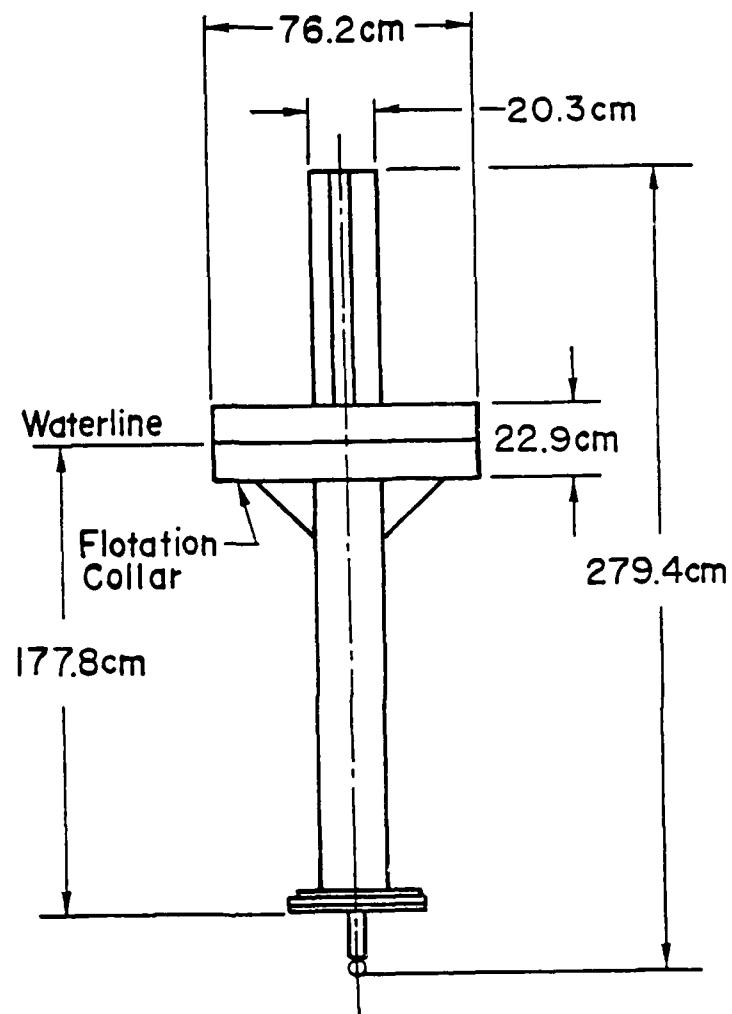


FIGURE 3

Small Buoy Hull Used in this Study

or buoy speeds in excess of 2 m/s, were discarded. Admittedly, this second test is subjective and conservative, but when a position was not clearly erroneous, it was retained. Using these criteria, approximately 75 percent of the original data was retained.

The resulting data set consisted of a series of positions separated by uneven time intervals. The average period between successive buoy positions was 1.4 days. However, on some occasions, there were four or five good positions per day, while on the other hand, there were several data gaps of up to ten days. A simple two-point linear interpolation scheme was used to generate a record which was equally spaced with a time interval ( $\Delta t$ ) of 48 hours.

### 2.1.3 Buoy Tracks

Seven free-drifting buoys were released in open water in 1979 in cooperation with Canadian Marine Drilling Limited (CANMAR). They were released on two dates, 9 August and 30 August 1979, at the CANMAR drilling sites north of Tuktoyaktuk, Northwest Territories (figures 1 and 4).

Of the seven, one (#235) grounded on Richards Island a short distance from the release site and another (#257) stopped transmitting almost immediately. The remaining five buoys traversed the Beaufort Sea in an east to west direction. Listings of the recorded buoy positions for these platforms are presented in appendix A.

The three buoys released on 9 August 1979 (#226, #432, and #443) moved persistently from east to west across the Beaufort Sea (figure 5) parallel to the Alaskan coast and approximately 200 km offshore. (The continental shelf, as defined by the 200 m contour, is approximately 80 km wide in this region.) To the west of Pt. Barrow, they turned slightly to the south and entered the Chukchi Sea where, by 11 February 1980, all had ceased transmitting.

The two surviving buoys (#261 and #404) from the 30 August 1979 release date also moved persistently along the Alaskan coast (figure 6) to the west, although somewhat inshore of the three released earlier. By mid-October 1979, these two buoys ceased transmitting. It is interesting to note that while buoy #261 was a large hull type and #404 was the small coastal version, their movements from the time they were released until they stopped transmitting were nearly identical, suggesting that differences in the hull type are not important in the present study.

A summary of the computed buoy speeds and directions is presented in figures 7 and 8. The buoy speeds are calculated from the interpolated data using a simple two-point backward difference. The most frequently occurring speeds are 0.10-0.30  $\text{ms}^{-1}$  while the most common directions are from 240° to 330°.

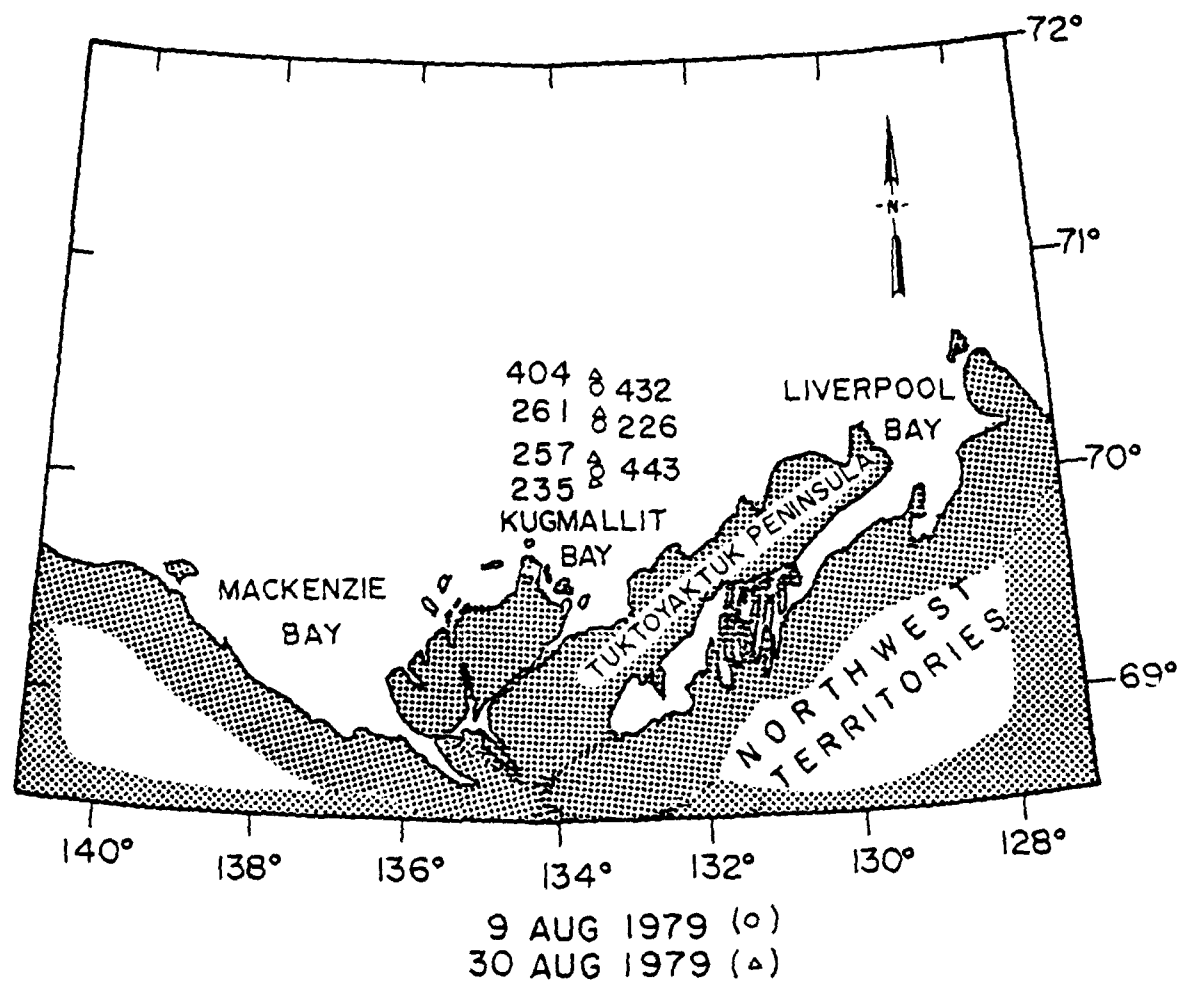


FIGURE 4

Release Site in the Southeastern Beaufort Sea

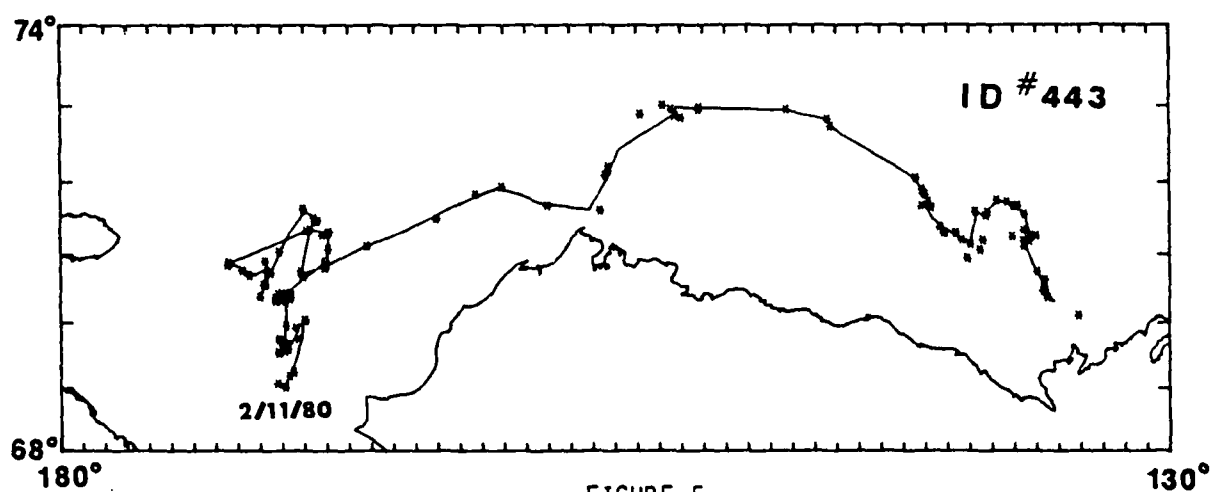
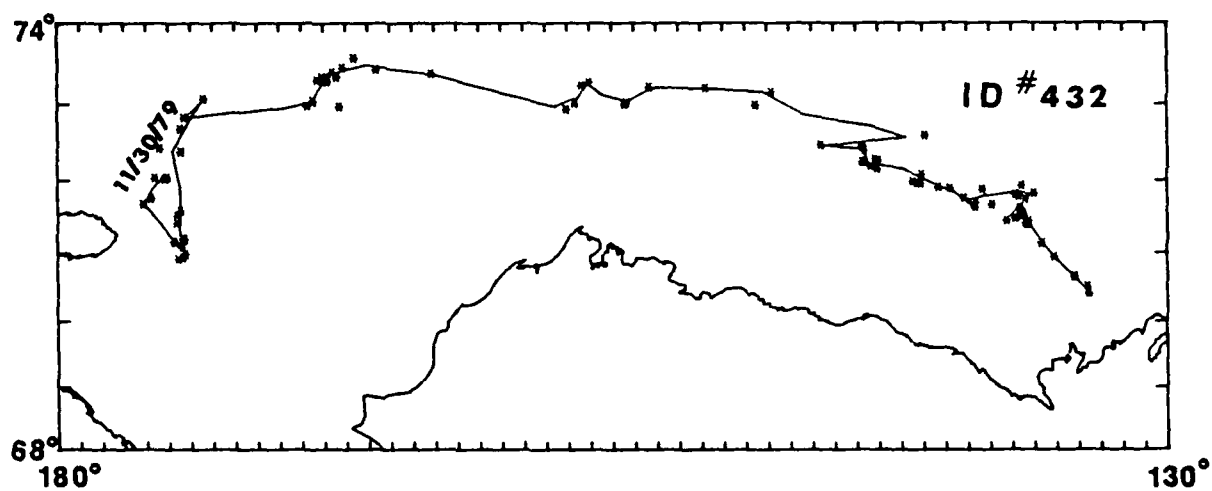
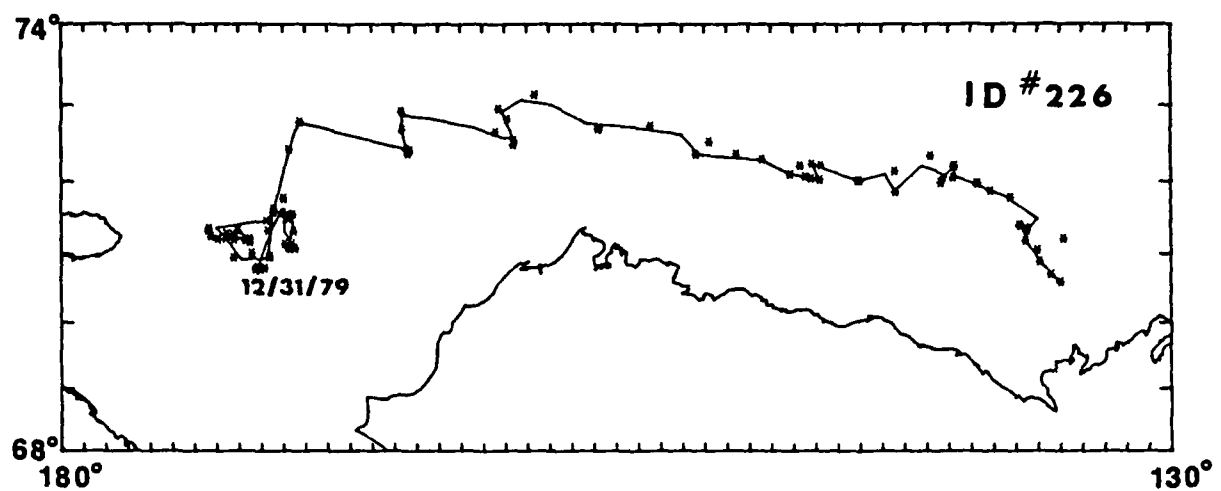


FIGURE 5

Tracks of Buoys Released on 9 August 1979.  
The asterisks indicate the raw buoy positions.

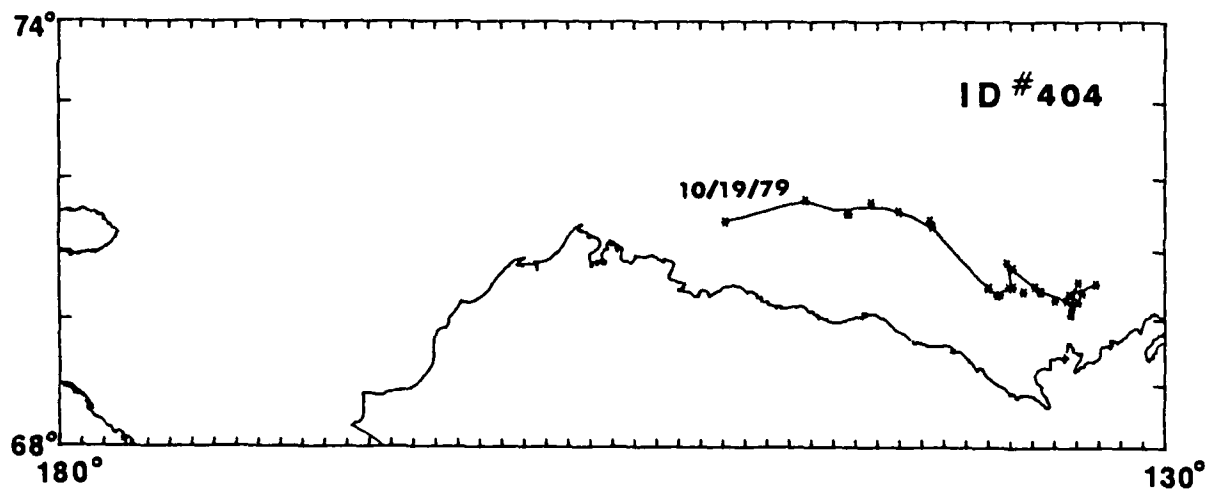
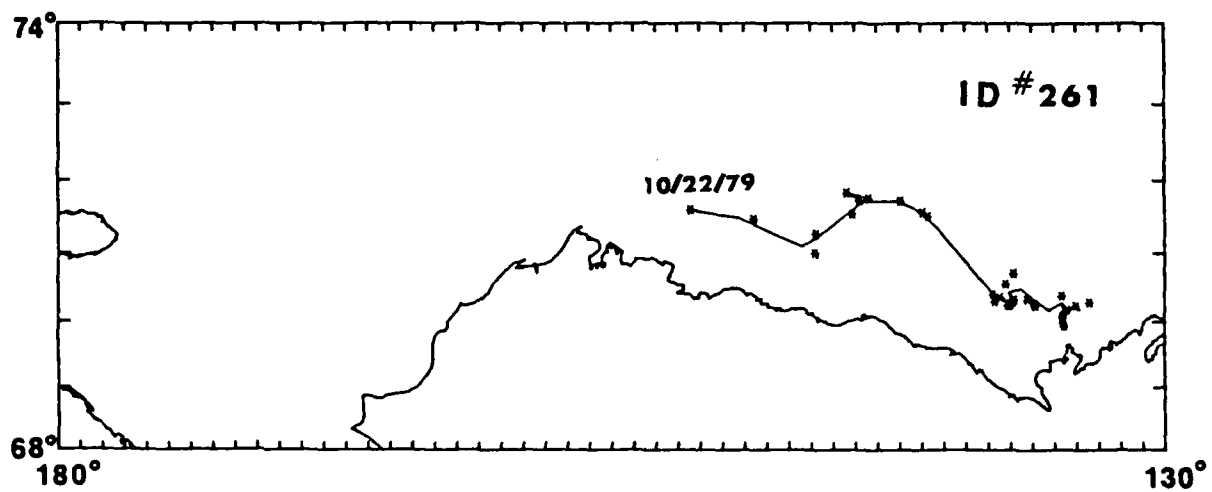


FIGURE 6

Tracks of Buoys Released on 30 August 1979.  
The asterisks indicate the raw buoy positions.

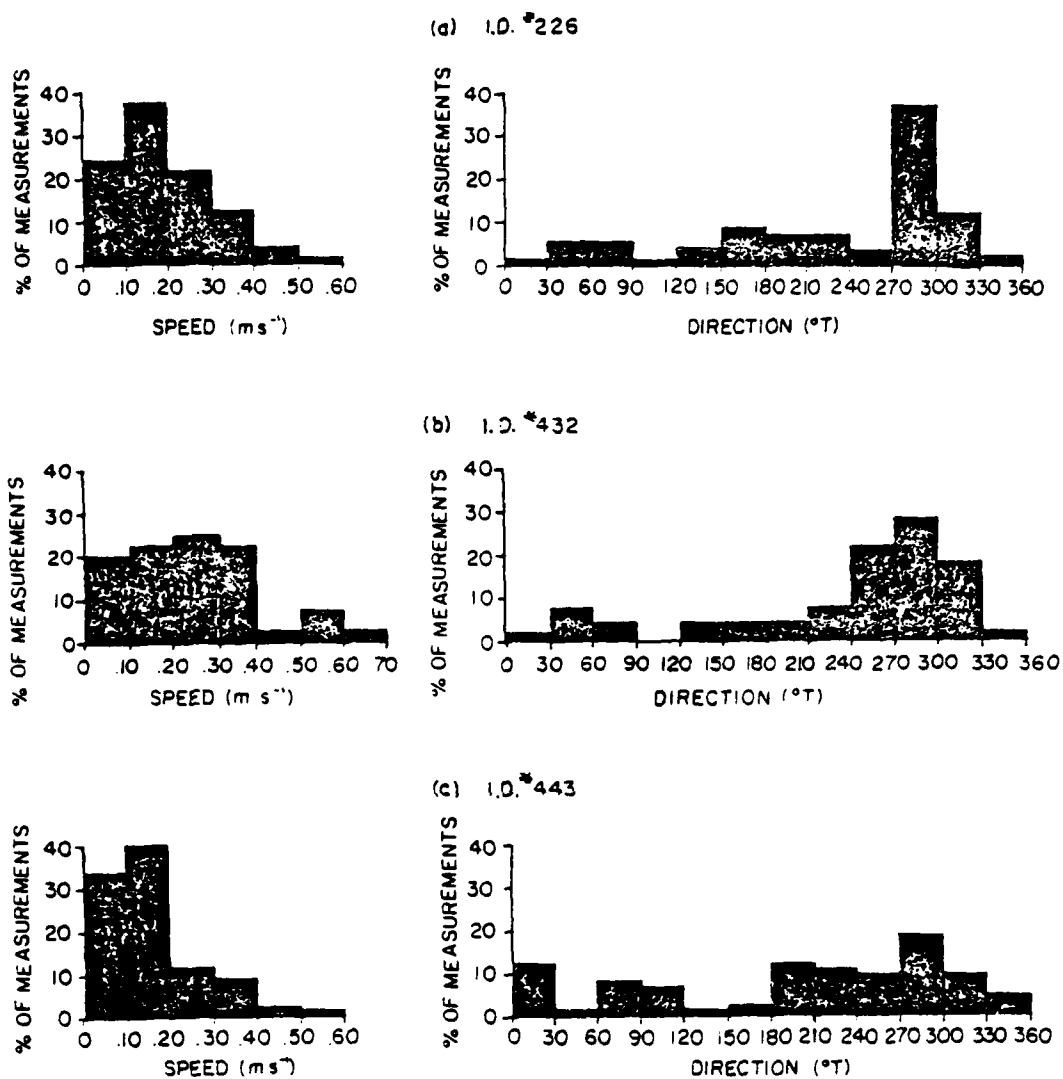


FIGURE 7

Distribution of 48-Hour Averaged Speed and Direction for  
(a) ID #226, (b) ID #432, (c) ID #443

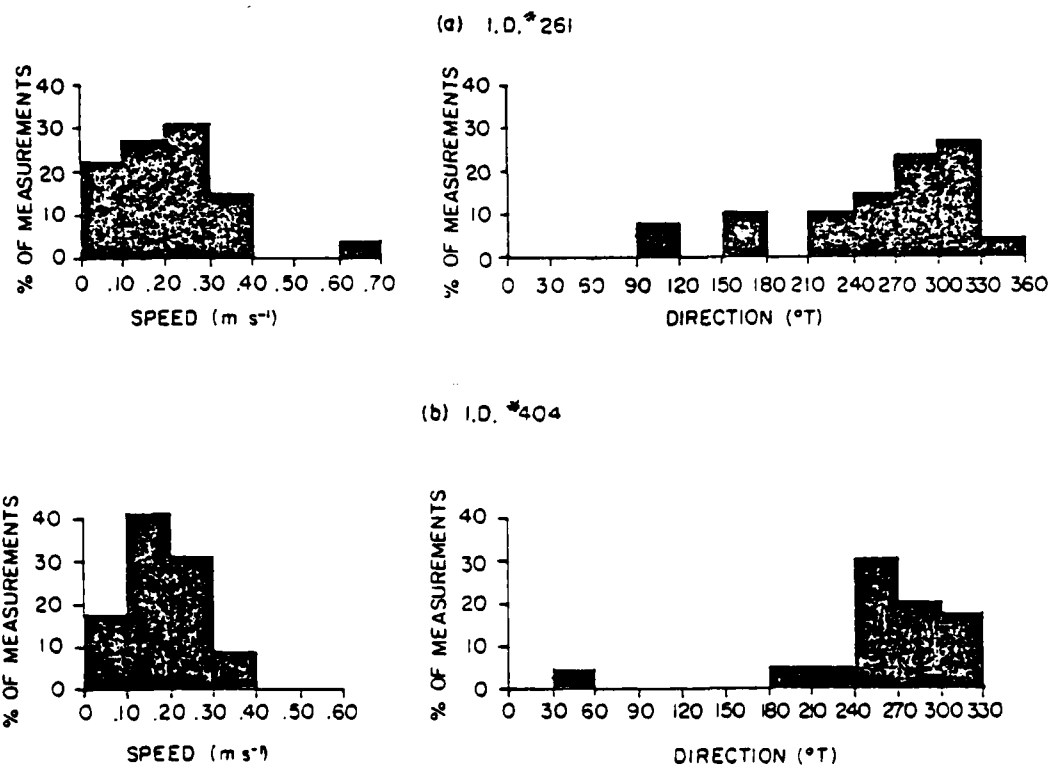


FIGURE 8  
Distribution of 48-Hour Averaged Speed and Direction for (a) ID #261,  
(b) ID #404

#### 2.1.4 Error Analysis

The effect on the velocity calculations of the time between fixes and the random error in the RAMS can be estimated using a few simplifying assumptions; the analysis follows, in part, that of Kirwan et al. (1976). First assume that the buoy position is a normally distributed random variable with a standard deviation of  $\sigma = 5$  km. The difference between successive positions is then normally distributed but with a standard deviation of 2 resulting in a standard deviation for the velocity values of:

$$V_{SD} = \frac{2\sigma}{\Delta t}$$

where  $\Delta t$  is the time interval between successive buoy positions.

To approximate the directional error, it is assumed that the buoy position is at the center of a circle of radius  $\sigma$ . A simplified depiction of the geometry is shown in figure 9. The angle  $\theta$  is the approximate maximum error in the computed direction. It can be calculated using

$$\theta = \tan^{-1} \left( \frac{\sigma}{0.5D} \right)$$

where  $D$  is the distance between buoy positions.  $D$  can be estimated using  $\Delta t$  and the average buoy speed ( $0.16 \text{ ms}^{-1}$ ).

For a standard deviation of position error of 5 km and a time interval of 48 hours, the equations above yield  $V_{SD} = 0.058 \text{ ms}^{-1}$  and  $\theta = 19.9^\circ$ . For a  $\Delta t = 168$  hours (one week),  $V_{SD} = 0.016 \text{ ms}^{-1}$  and  $\theta = 5.9^\circ$ .

#### 2.2 Ice Edge Position

Because the buoys were moving in the dynamic ice environment, it is important to consider the position of the ice edge in the Beaufort and Chukchi Seas during the period that they were transitting. Ice edge analysis was obtained from the Navy-NOAA Joint Ice Center in Suitland, Maryland. Biweekly analyses are presented here for the period 7 August to 13 November 1979 and for 20 November 1979 (figures 10-13) is also presented. The approximate positions of the buoys on these dates are also shown in these figures. The ice concentrations are presented in tenths. Open water refers to ice concentrations of  $< 1/10$  and ice-free indicates that there is no sea ice present. The ice is also classified by age; multi-year and second-year ice are indicated by OLD (2.0 to 3.0 m thick) while first-year ice (FY) includes all first-year ice types ( $\sim 30$  cm to 2 m thick). Young ice (10 to 30 cm) is denoted by YNG, and N refers to new and nilas.

In the Beaufort Sea the buoys moved primarily in ice-free waters. An exception occurs at the end of October when the two buoys from the second release (#261 and #404) became entrapped in ice and ceased transmitting.

In the Chukchi Sea the interactions between the buoys and ice were more complex. On 30 October, two of the three remaining buoys (#226 and #432) were

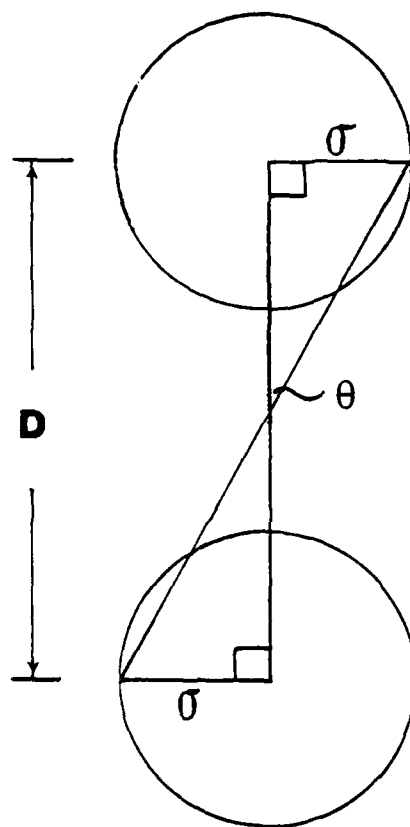
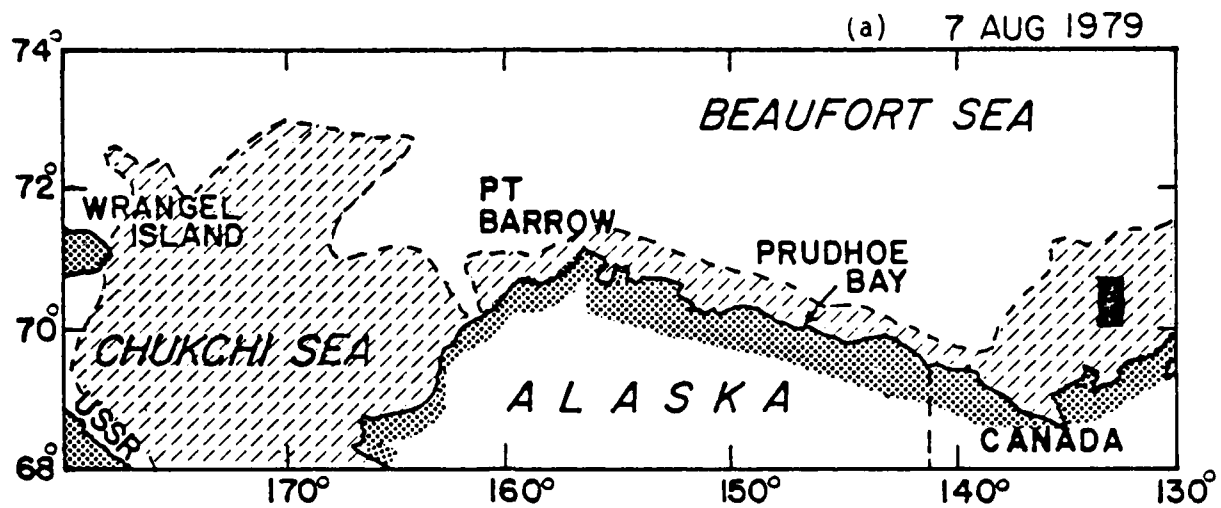
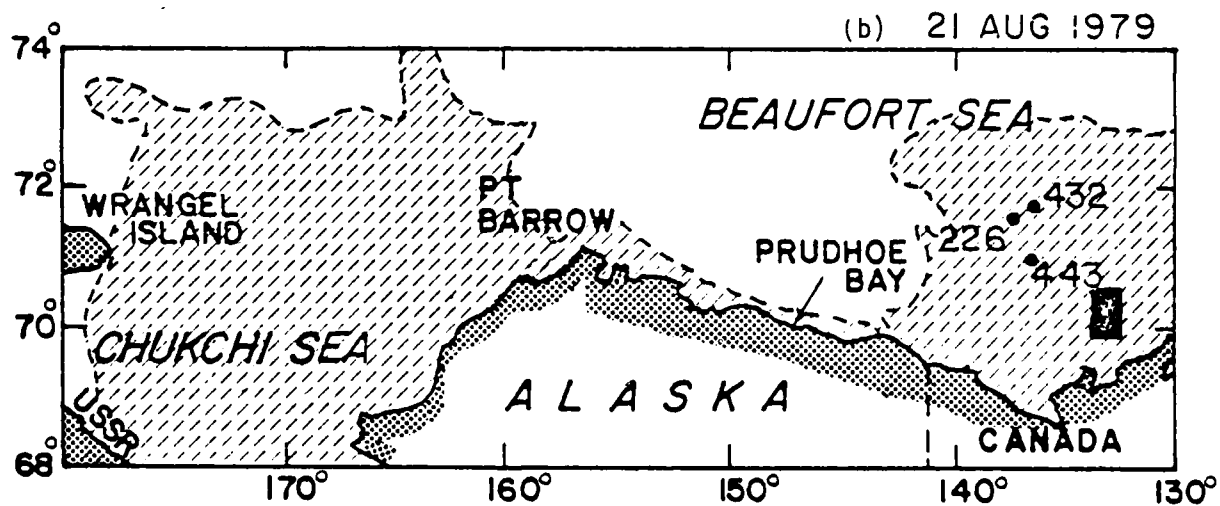


FIGURE 9  
Definition Sketch for Directional Error Analysis



----- = ICE FREE

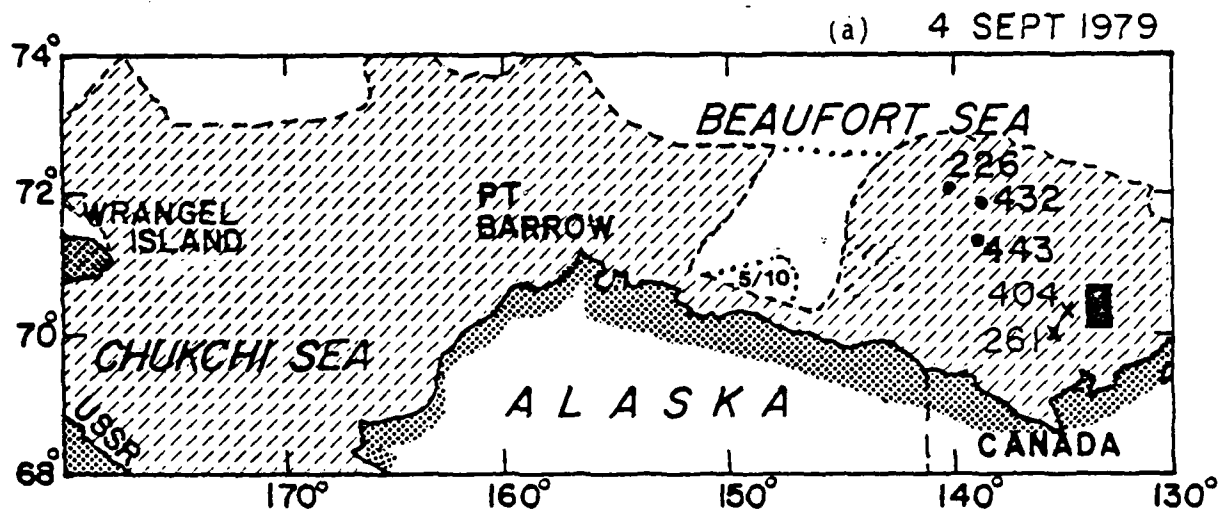


----- = ICE FREE

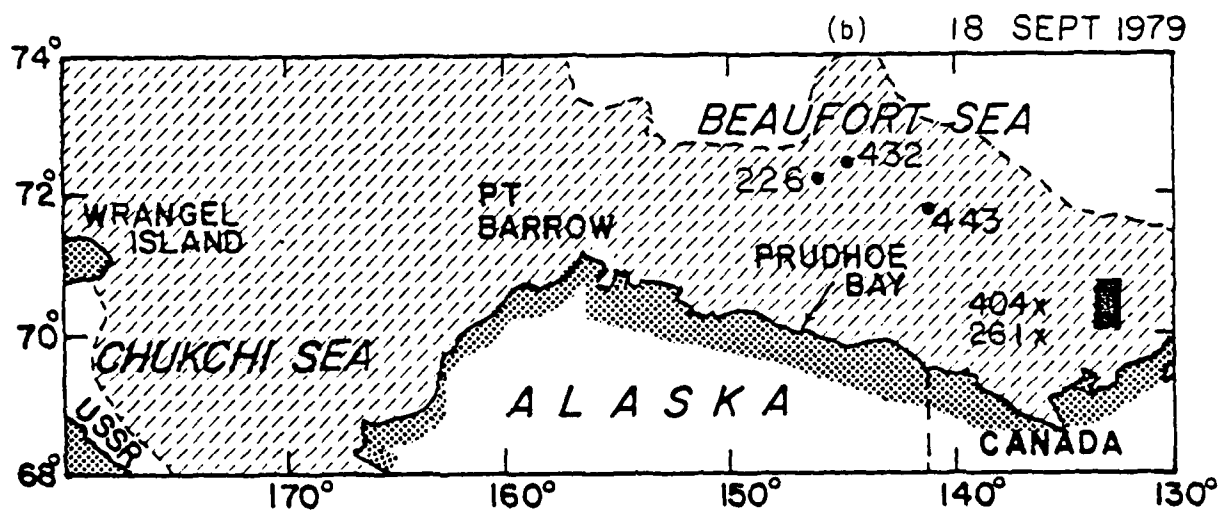
• = BUOYS RELEASED  
ON 9 AUG

FIGURE 10

Ice Edge Position on (a) 7 August 1979 and (b) 21 August 1979



===== = ICE FREE  
 ..... = OPEN WATER  
 (<1/10)



===== = ICE FREE

FIGURE 11

Ice Edge Position on (a) 4 September 1979 and (b) 18 September 1979

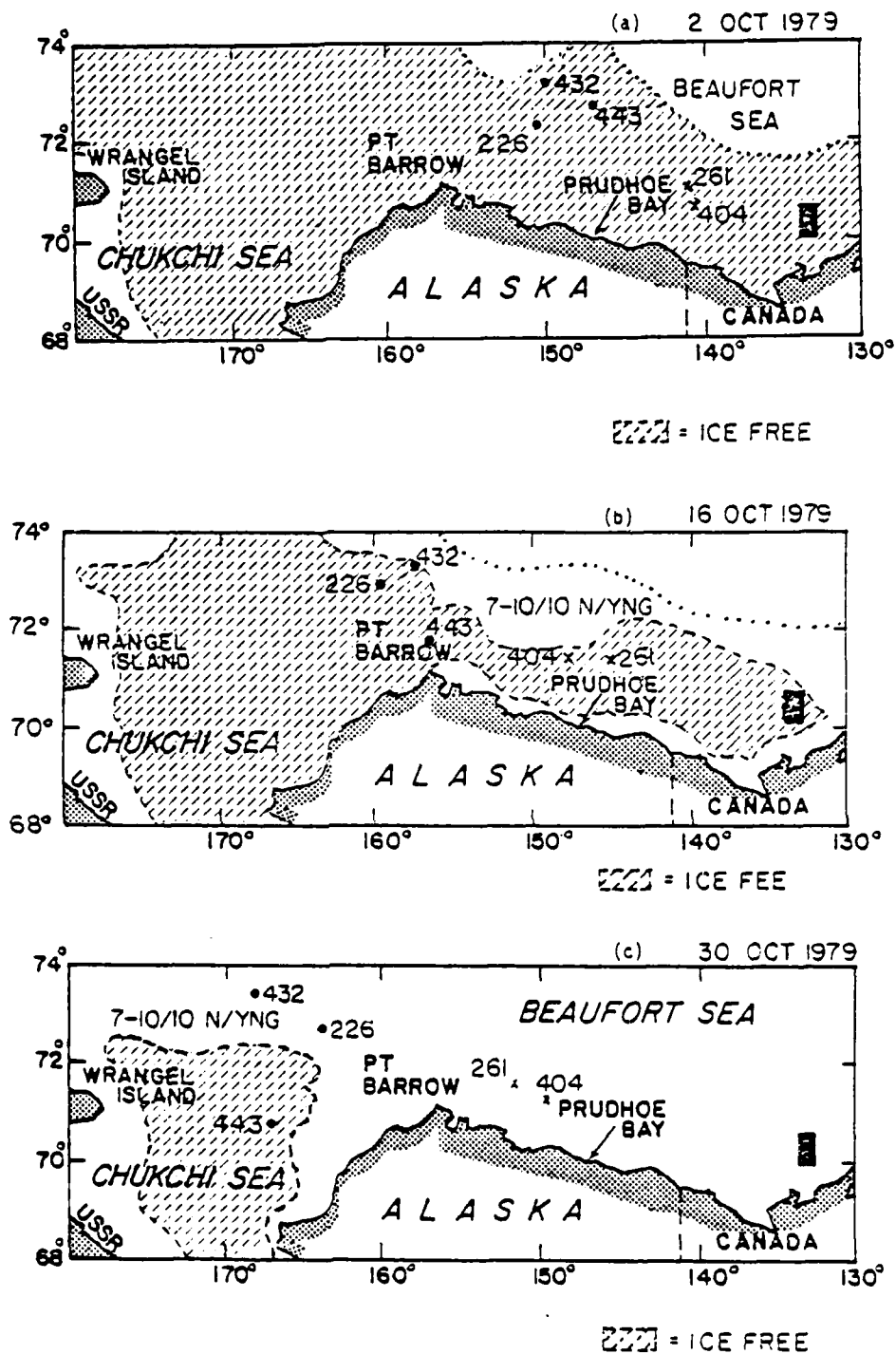


FIGURE 12

Ice Edge Position on (a) 2 October 1979, (b) 16 October 1979, and  
(c) 30 October 1979

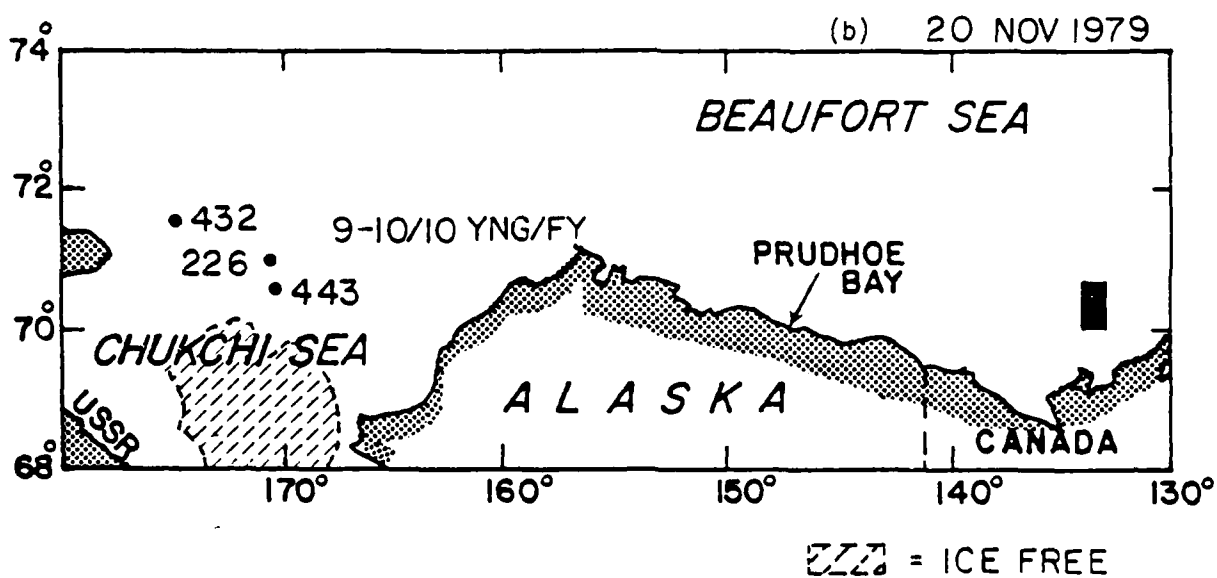
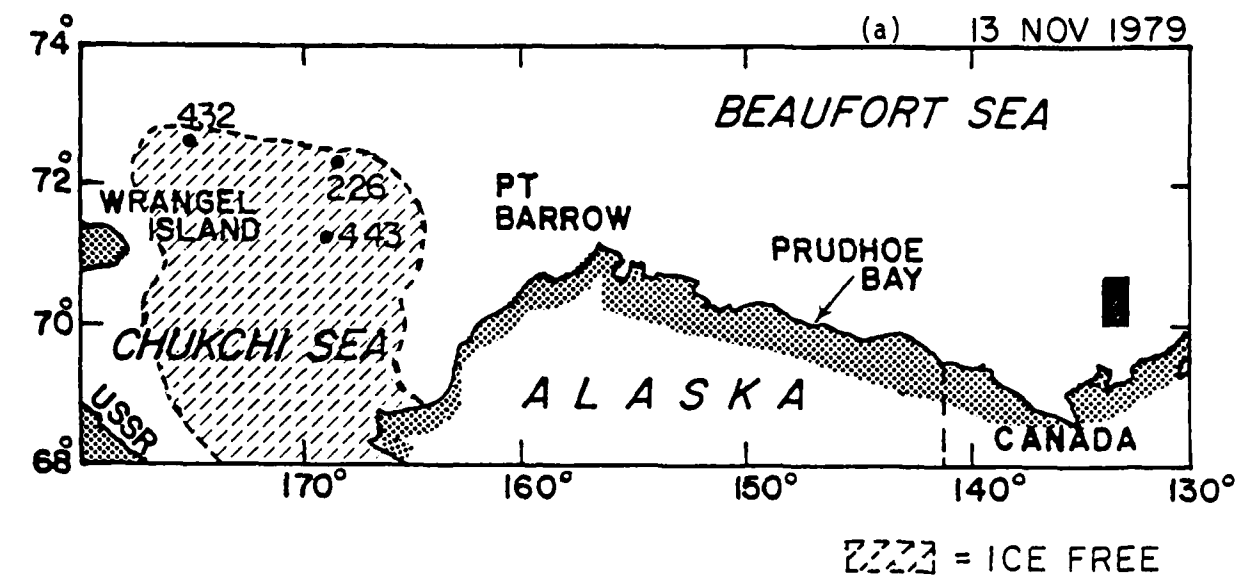


FIGURE 13

Ice Edge Position on (a) 13 November 1979 and (b) 20 November 1979

in 7-10/10 N/YNG ice; by 13 November (figure 13a) they were in ice-free water near the ice edge. One week later, however, all three buoys were in 9-10/10 young and new ice. It is worth emphasizing that these buoys were in a region of newly forming ice and not being driven to the south with multi-year ice. Because the major emphasis of the present analysis is on the atmospheric forcing of the surface flow during open water conditions, only buoy movement before 20 November 1979 will be considered.

### 2.3 Wind Data

Surface wind data available for the Arctic are limited to that gathered at shore stations on the perimeter of the Arctic Ocean. Data from these stations are not, in general, representative of the surface winds offshore. As a result, the wind field used for comparison with buoy movements was generated using the National Meteorological Center (NMC) 1000 mb velocity field from the archives at the National Center for Atmospheric Research (NCAR).

The details of the NMC analysis are described in Bergman (1979) and McPherson et al. (1979). Essentially, a wind field is generated by using the 12-hour forecast obtained from the nine-layer global prediction model as a first-guess field. This is then updated using available data, for example, atmospheric pressure from land stations. In the Arctic, of course, this method is severely limited by the paucity of data for updating the first guess. The data are provided by NCAR in the form of an x,y grid overlaid on a polar stereographic projection of the northern hemisphere. As a result, the grid spacing between data points varies as a function of latitude. In the Beaufort Sea, the NMC grid spacing is approximately 400 km.

The 1000 mb wind velocity field is adjusted to account for the frictional effects of the surface boundary layer by applying a simple relationship between geostrophic wind and the actual surface winds. The actual surface wind is assumed to be 65% of the geostrophic wind at  $25^{\circ}$  to the left of the isobar (Petterssen, 1958). These values can, of course, change significantly as a function of the surface roughness, the geostrophic wind speed and the thermal structure of the atmosphere. However, given the sparse nature of the data inputs to the wind field and the relatively coarse grid, a sophisticated boundary layer model is unwarranted. Moreover, the values of 65% and  $25^{\circ}$  are defensible based on data reported from Albright (1980) who, using data collected during the Arctic Ice Dynamics Joint Experiment (AIDJEX), found that during the summer, the values over the ice were  $\sim 60\%$  at  $24^{\circ}$ .

### 3.0 COMPARISON OF DRIFTER TRACKS WITH THE MEAN FLOW FIELD

The mean circulation in the Beaufort Sea is dominated by the east to west flow of the southern portion of the anticyclonic Beaufort Sea Gyre. The dynamic topography, referenced to 500 decibars, is shown in figure 14 (Newton, 1973). The mean flow approximately follows the bathymetric contours in the region along the northern Alaskan coast. Near Pt. Barrow, the flow turns to the northwest, roughly paralleling the break of the Chukchi Sea shelf. The mean current speed in the southern portion of the Beaufort Sea Gyre is approximately  $0.03-0.05 \text{ ms}^{-1}$ .

In comparing the buoy trajectories with the mean flow field, it is important to recognize the limitations of the calculated geostrophic current field. The data used to construct the dynamic topography were gathered over many years without regard to season. As a result, the currents calculated using this topography are not synoptic. Moreover, there is no information on the temporal variability of the Beaufort Sea Gyre.

There are two major differences between the surface flow indicated by the buoy movements and that calculated from the mass distribution. First, while the gyre turns to the northwest near Pt. Barrow, the three buoys (#226, #432, and #443) from the first release moved onto the Chukchi Sea shelf. Second, while the buoys were moving in the southern part of the gyre (east of Pt. Barrow), typical buoy speeds were  $\sim 3$  times the calculated mean current. These movements are attributed to wind as described in the next section.

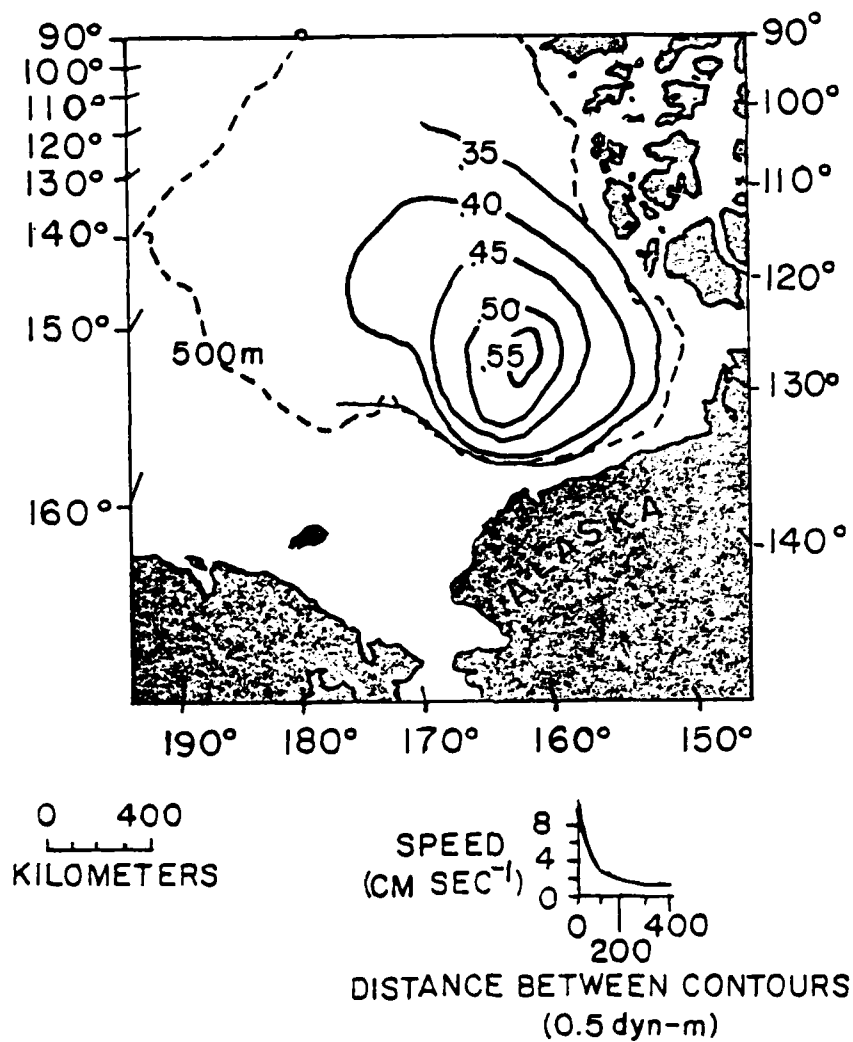


FIGURE 14

Dynamic Topography of the Canada Basin  
(after Newton, 1973).

#### 4.0 COMPARISON OF DRIFTER TRACKS WITH SURFACE WINDS

Because of the crude nature of the wind data and the data gaps in the buoy movement records, weekly averages were used to compare the buoy movements with the surface winds. Weekly averaged wind vectors were calculated in areas of  $5^\circ$  of latitude by  $10^\circ$  of longitude, a grid somewhat coarser than the original NMC wind file. The weekly average buoy speed and direction were then calculated for all of the buoys moving within each  $5^\circ \times 10^\circ$  area.

A simple comparison between the surface wind speed and the buoy speed is shown in figure 15. Although there is a great deal of scatter in the data, it is evident that the buoy speed increases with increasing wind speed. For example, a 5-fold increase in wind speed (2 to 10 m/s) results in a 2.5-fold increase in buoy speed.

Other comparisons involve the calculation of the buoy speed as a percentage of the surface wind speed (wind factor) and, also, the deflection angle, which is defined as the direction of the buoy movement minus the wind direction. Figure 16 shows the deflection angle in terms of percent occurrence. A positive angle means that the buoy moved to the right of the wind; negative angles imply movement to the left of the wind. In the aggregated data there is considerable scatter, but at higher surface wind speeds, the buoys move exclusively to the right of the wind, most frequently in the range of  $20^\circ$  to  $30^\circ$ .

The data from the calculations are summarized in table 1. Again, the aggregated data show considerable scatter, as indicated by standard deviations which exceed the mean values. For wind speeds greater than 5 m/s, however, the buoys moved consistently at 3.8% of the wind speed and  $22^\circ$  to the right of the wind. It should be emphasized that the buoy movement data used for these computations were those in which the buoys were in open or ice-free water.

TABLE 1

Mean ( $\bar{x}$ ) and Standard Deviation (S.D.) of Wind Factor and Deflection Angle  
as a Function of Surface Wind Velocity

WIND SPEED	$\bar{x} \pm \text{S.D.}$ BUOY SPEED WIND SPEED	$\bar{x} \pm \text{S.D.}$ DEFLECTION ANGLE (degrees)
ALL DATA	$8.9\% \pm 12.2$	$34^\circ \pm 56$
$w \geq 2.5 \text{ M/S}$	$4.9\% \pm 2.8$	$30^\circ \pm 44$
$w \geq 5.0 \text{ M/S}$	$3.8\% \pm 1.3$	$22^\circ \pm 15$

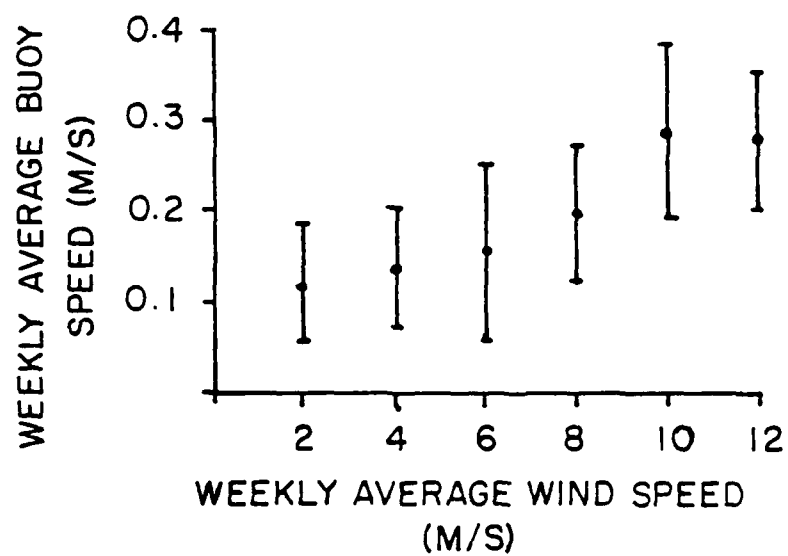


FIGURE 15

Weekly Averaged Buoy Speed Versus Weekly Averaged Wind Speed

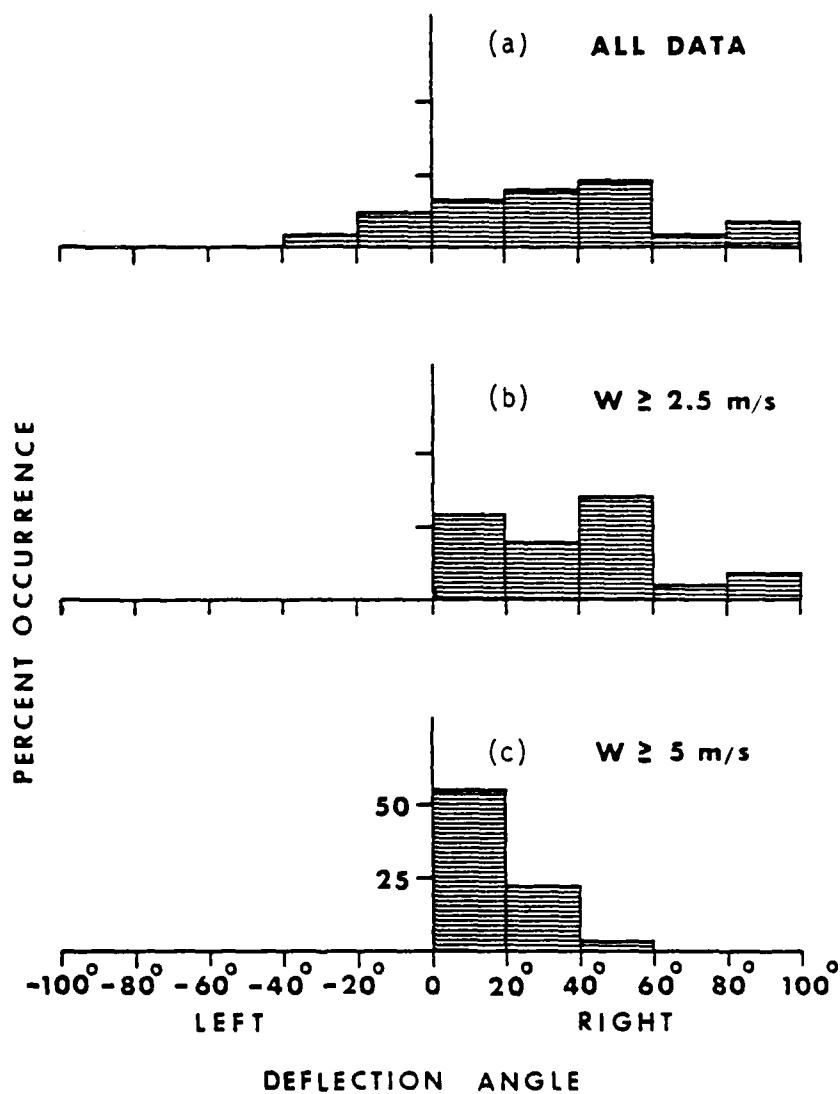


FIGURE 16

Deflection angle for (a) the aggregated data, (b)  $w \geq 2.5$  m/s and (c)  $w \geq 5$  m/s

## 5.0 DISCUSSION

The analysis of the data presented in this report is preliminary but the comparisons between the surface winds and the buoy movements clearly indicate that a correlation exists at wind speed greater than  $5 \text{ ms}^{-1}$ . The buoys were observed to move  $22^\circ$  to the right of the local wind at 3.8 percent of the wind speed. These values compare favorably with other investigations of wind drift currents. For example, McNally (1981) found that the near-surface flow in the north Pacific ocean, as indicated by free-drifting buoys, was  $20\text{-}30^\circ$  to the right of the wind at approximately 1.5 percent of the wind speed. Zubov (1943), using drift data from ice station and ice-entrapped vessels in the Arctic Ocean, found that sea ice moves approximately  $30^\circ$  to the right of the local wind at 2 percent of the wind speed. There is, however, considerable scatter in the literature values as discussed by Huang (1979); values of from 0 to  $50^\circ$  and 1 to 7 percent have been reported.

A combination of several factors is likely to be responsible for the scatter at low wind speed observed in the present study. First, it is clear that in the Arctic there are inadequate meteorological data. The details of the pressure distribution, from which the winds are calculated, are poorly known. For a strong atmospheric signal, like the passage of an intense low through the region, the present data collection system is adequate because the signal is overwhelming and the pressure distribution can be inferred from a few stations. For weak signals, which result in lower wind speeds, the details of the pressure distribution cannot be adequately determined from a few data points. Second, complicating an already grim picture of the wind field at low speeds is the fact that the relationship between the geostrophic winds and the surface winds is poorly known at low wind speed. Finally, at low wind speeds, the motion of the buoys is likely to be strongly affected by factors other than local wind forcing such as the seasonal mean circulation.

The preliminary results presented have some important implications concerning the long-term movement of large Arctic oil spills. In a summer, open-water spill the timing of the spill is important in determining where the spill will become incorporated in the ice. The buoy trajectories showed that those buoys released on 9 August entered significant ice concentrations in the Chukchi Sea in mid-November. On the other hand, the buoys released three weeks later were entrapped in ice in the Beaufort Sea north of Prudhoe Bay (over 800 kilometers to the east) in mid-October. The importance of monitoring the position of the ice edge during the movement of a spill and tagging the spill with a satellite-tracked buoy is obvious.

## 6.0 CONCLUSIONS

The following are some preliminary conclusions:

1. During open water season, the surface waters of the Beaufort Sea are wind driven and, thus, the surface flow can be different from the historical geostrophic flow of the Beaufort Sea Gyre.
2. For high wind speed ( $\geq 5 \text{ ms}^{-1}$ ), the near-surface flow in the Beaufort Sea is  $22^\circ$  to the right of the wind at 3.8 percent of the surface wind speed.
3. At low wind speeds, it is difficult to predict the surface flow in the Beaufort Sea from the wind alone.
4. In the Arctic, there is inadequate meteorological data to predict the surface flow. Direct wind measurements are virtually nonexistent and surface atmospheric pressure data are sparse.
5. The position of the ice edge is important because significant ice concentrations can act as a barrier to the movement of drifters.

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APPENDIX A  
RAW BUOY DATA  
BUOY #226

ORBIT	JULIAN DATE	TIME HHMMSS	LAT.	LONG.
20425	227	051731	70.60	134.98
20453	229	162548	70.71	135.42
20466	230	050142	70.89	135.93
20471	230	153520	71.05	136.05
20489	231	235645	71.19	136.58
20506	233	043826	71.41	136.83
20514	233	184628	71.39	136.78
20518	234	020701	71.35	136.51
20531	235	031418	71.36	136.56
20537	235	120843	71.34	136.53
20546	236	060710	71.32	136.52
20548	236	094031	71.22	134.86
20600	239	162604	71.78	137.24
20615	241	094403	71.88	138.14
20639	243	044635	71.98	138.71
20641	243	081955	71.98	138.78
20642	243	100636	72.06	139.81
20679	246	042631	72.21	139.75
20681	246	080056	72.21	139.82
20706	248	045115	72.06	140.25
20733	248	204555	71.99	140.37
20752	251	080634	72.34	140.83
20800	253	223917	71.86	142.43
20801	255	070355	72.14	142.46
20837	257	214408	72.01	144.03
20841	258	064457	72.01	144.13
20864	259	235634	72.24	146.18
20867	260	052155	72.22	145.78
20895	261	203403	72.02	145.82
20904	262	162120	72.04	146.21
20920	264	042023	72.07	146.48
20927	264	164354	72.21	146.72
20929	264	182826	72.10	147.15
21056	274	061626	72.30	148.43
21072	274	183644	72.37	149.58
21081	276	030019	72.36	151.40
21101	276	204807	72.53	150.79
21122	279	061859	72.74	153.45
21147	281	045348	72.71	155.76
21150	281	064236	72.69	155.81
21201	285	020120	73.13	158.67
21237	287	182605	72.95	160.29
21246	288	104313	72.82	159.92
21269	290	054546	72.54	159.57
21276	290	162236	72.49	159.62

## RAW BUOY DATA

BUOY #226

ORBIT	JULIAN DATE	TIME HHMMSS	LAT.	LONG.
21308	293	033553	72.66	160.43
21363	297	061302	72.92	164.68
21435	302	113746	72.69	164.64
21492	306	192625	72.37	164.38
21496	306	212242	72.43	164.45
21497	307	061916	72.42	164.29
21639	317	185211	72.79	169.25
21643	317	222428	72.79	169.27
21686	321	123556	72.43	169.74
21719	323	181522	71.59	170.44
21728	324	121600	71.33	170.70
21738	324	210258	71.01	171.43
21743	325	132111	70.97	170.61
21750	325	220913	70.96	170.65
21755	326	123837	70.80	170.85
21782	328	130219	70.95	172.25
21792	328	214813	71.21	172.94
21804	329	225324	71.22	172.57
21830	331	212923	71.33	172.05
21857	333	200524	71.21	171.52
21859	334	070232	71.16	171.50
21864	334	142202	71.28	172.26
21873	334	225717	71.19	171.70
21876	335	114106	71.20	172.20
21884	335	202805	71.29	172.56
21888	336	105937	71.24	173.27
21893	336	180203	71.32	173.41
21898	336	213316	71.36	173.35
22018	345	222233	71.47	170.76
22045	347	205833	71.64	170.41
22047	348	060755	71.59	170.44
22060	349	052625	71.58	169.98
22064	349	123411	71.49	169.77
22081	350	185406	71.54	169.67
22086	350	222623	71.56	169.56
22113	352	225008	71.32	169.54
22121	353	184808	71.09	169.80
22136	354	175457	71.09	169.70
22139	355	010244	71.07	169.71
22143	355	100959	71.09	169.63
22153	355	223020	71.14	169.62
22158	356	130049	71.08	169.47
22172	356	214749	71.15	169.95
22215	360	191449	71.77	169.99
22254	363	165739	70.77	171.26

# RAW BUOY DATA

BUOY #226

ORBIT	JULIAN DATE	TIME HHMMSS	LAT.	LONG.
22267	363	221429	70.79	171.21
22269	364	194621	70.80	171.10
22270	364	233127	70.81	171.15
22272	365	030240	70.79	171.03
22272	365	030240	70.79	171.03
22272	365	030240	70.79	171.03

## RAW BUOY DATA

BUOY #235

ORBIT	JULIAN DATE	TIME HHMMSS	LAT.	LONG.
20733	248	204918	69.31	135.79
20801	255	070530	69.49	135.81
20806	255	122530	69.35	135.13
20821	256	132823	69.26	135.26
20834	257	143326	69.24	135.21
20836	257	181101	69.31	135.80
20840	258	050037	69.29	135.44
20867	260	052257	69.31	135.81
20895	261	203807	69.32	135.77
20904	262	162101	69.30	135.81
20911	263	120916	69.30	135.80
20929	264	183313	69.34	135.72
21056	274	061655	69.32	135.81
21072	274	184126	69.32	135.71
21101	276	205028	69.32	135.77
21122	279	062105	69.28	135.77
21148	281	045855	69.34	135.90
21150	281	064326	69.29	135.79
21193	284	132842	69.30	135.76
21205	285	110129	69.16	135.64
21237	287	182822	69.33	135.70
21246	288	104629	69.28	135.75
21276	290	162330	69.30	135.78
21296	292	061112	69.31	135.81
21336	295	055157	69.26	135.72
21362	296	191820	69.30	135.78
21379	298	105034	69.30	135.78
21430	302	061830	69.27	135.73
21435	302	113621	69.29	135.82
21483	306	051737	69.26	135.63
21492	306	192744	69.31	135.79
21497	307	062240	69.30	135.78
21635	316	212141	69.32	135.79
21639	317	185220	69.34	135.64
21686	321	123226	69.43	134.97
21691	321	160442	69.15	135.03
21719	323	181344	69.46	134.86
21728	324	121519	69.30	135.82
21750	325	221341	69.31	135.79
21755	326	123636	69.30	135.82
21766	327	063812	69.29	135.77
21825	331	161303	69.31	135.85
21830	331	213303	69.33	135.79
21857	333	200845	69.31	135.78
21865	334	155348	69.31	135.82

# RAW BUOY DATA

BUOY #235

ORBIT	JULIAN DATE	TIME HHMMSS	LAT.	LONG.
21884	335	203211	69.33	135.78
21893	336	180146	69.31	135.92
21898	336	213818	69.33	135.76
22047	348	061110	69.29	135.76
22060	349	052934	69.27	135.71
22064	349	123302	69.30	135.82
22081	350	185557	69.32	135.78
22136	354	175505	69.30	135.87
22143	355	101105	69.26	135.66
22254	363	165932	69.31	135.82
22269	364	194907	69.32	135.80
22281	365	172050	69.31	135.83
22317	368	100119	69.23	135.51

# RAW BUOY DATA

BUOY #261

ORBIT	JULIAN DATE	TIME HHMMSS	LAT.	LONG.
20632	242	160335	69.99	134.63
20639	243	044617	70.28	133.43
20679	246	042820	70.18	134.43
20733	248	204534	70.08	134.65
20800	253	223957	69.94	134.56
20801	255	070434	70.38	134.67
20806	255	122331	70.23	134.05
20821	256	043621	70.10	134.58
20836	257	181124	70.24	135.89
20837	257	214340	70.26	135.88
20841	258	064534	70.33	136.22
20864	259	235605	70.71	136.86
20867	260	052230	70.56	137.22
20895	261	203436	70.29	136.88
20904	262	161944	70.33	136.82
20911	263	120803	70.26	136.99
20912	263	135340	70.24	137.06
20920	264	042054	70.25	137.14
20927	264	164216	70.30	137.71
20929	264	182754	70.37	137.44
20934	265	033922	70.41	137.78
21056	274	061545	71.51	140.72
21072	274	183603	71.57	140.95
21101	276	204725	71.73	141.93
21122	279	062024	71.73	143.81
21150	281	064154	71.84	144.36
21201	285	020244	71.76	143.36
21208	285	161711	71.54	144.13
21246	288	104749	71.27	145.78
21276	290	162255	70.99	145.83
21296	292	060839	71.48	148.59
21336	295	055046	71.60	151.43

# RAW BUOY DATA

BUOY #404

ORBIT	JULIAN DATE	TIME HHMMSS	LAT.	LONG.
20639	243	044609	70.53	133.10
20733	248	204513	70.38	134.29
20775	253	064131	70.55	133.90
20800	253	223924	70.08	134.25
20806	255	122359	70.40	133.70
20807	255	155823	70.27	133.90
20821	256	043648	70.29	134.41
20822	256	185529	70.18	134.17
20834	257	143306	70.30	134.94
20836	257	181042	70.42	135.57
20837	257	214403	70.43	135.64
20840	258	045915	70.50	135.85
20841	258	064555	70.43	136.36
20864	259	235622	70.83	137.11
20867	260	052143	70.76	136.85
20895	261	203346	70.50	136.86
20904	262	161956	70.48	137.05
20911	263	120917	70.38	137.42
20920	264	042102	70.37	137.55
20927	264	164223	70.48	137.95
20929	264	182759	70.47	137.96
21056	274	061530	71.35	140.50
21072	274	183547	71.43	140.61
21101	276	204600	71.55	142.01
21122	279	061958	71.68	143.25
21148	281	045547	71.53	144.26
21150	281	064227	71.53	144.36
21188	284	024547	71.71	146.23
21296	292	060848	71.41	149.86

## RAW BUOY DATA

BUOY #432

ORBIT	JULIAN DATE	TIME HHMMSS	LAT.	LONG.
20385	224	053526	70.51	133.61
20398	225	045356	70.41	133.56
20424	227	013959	70.66	134.19
20425	227	051632	70.67	134.23
20453	229	054013	70.94	135.11
20466	230	050050	71.14	135.67
20495	232	085440	71.52	136.46
20499	232	155706	71.56	136.54
20506	233	043845	71.63	136.65
20514	233	184545	71.61	136.62
20518	234	020619	71.55	136.50
20519	234	054355	71.51	136.60
20521	234	091716	71.48	136.86
20523	234	124933	71.78	136.74
20531	235	031337	71.45	136.25
20537	235	120803	71.42	136.42
20546	236	060632	71.40	136.35
20548	236	093953	71.46	137.26
20583	239	021210	71.75	136.43
20600	239	162638	71.81	136.85
20614	241	075656	71.83	136.03
20630	242	123424	71.93	136.58
20639	243	044612	71.82	136.87
20641	243	082037	71.68	137.91
20679	246	042823	71.88	138.34
20681	246	080144	71.76	139.16
20706	248	045100	71.70	138.64
20733	248	204545	71.63	138.66
20821	256	043548	71.89	139.79
20834	257	143317	71.91	140.30
20836	257	181054	71.96	141.10
20837	257	214416	71.97	141.26
20840	258	045722	71.98	141.46
20841	258	064506	72.09	141.05
20864	259	235646	72.27	143.03
20867	260	052103	72.29	143.19
20895	261	203419	72.16	143.05
20904	262	162032	72.19	143.34
20911	263	120854	72.25	143.67
20912	263	135431	72.44	143.74
20920	264	041939	72.26	143.77
20929	264	182847	72.40	143.66
20935	265	071234	72.46	143.74
20962	267	040047	72.47	145.60
20990	269	094430	72.60	140.91

## RAW BUOY DATA

BUOY #432

ORBIT	JULIAN DATE	TIME HHMMSS	LAT.	LONG.
21057	274	094817	72.99	148.54
21072	274	183723	73.15	147.83
21101	276	204746	73.21	150.79
21122	279	061843	73.22	153.34
21147	281	045441	73.02	154.35
21150	281	064225	73.00	154.44
21193	284	133016	73.24	156.39
21201	285	020116	73.28	156.06
21237	287	183230	73.01	156.68
21246	288	104731	72.93	157.07
21336	295	054836	73.39	163.16
21362	296	191617	73.43	165.65
21363	297	061220	73.58	166.64
21375	298	033851	73.46	167.16
21379	298	105054	73.40	167.63
21389	299	025411	73.35	168.09
21396	299	154007	72.97	167.30
21402	299	205657	73.31	168.30
21429	302	023523	73.30	167.94
21430	302	061509	73.29	167.83
21431	302	080253	73.34	167.41
21435	302	113614	73.31	167.85
21457	304	063853	73.35	167.88
21492	306	192402	73.04	168.48
21496	306	212331	73.04	168.48
21497	307	061902	72.97	168.74
21635	316	211821	72.83	174.29
21639	317	185012	72.69	174.46
21643	317	222333	72.68	174.45
21653	318	214101	73.07	173.41
21670	320	041759	72.43	175.41
21686	321	123406	72.39	174.45
21719	323	181337	71.59	174.47
21727	324	031429	71.53	174.63
21728	324	121520	71.42	174.63
21743	325	132033	71.21	174.34
21744	325	151858	71.18	174.30
21750	325	220732	71.20	174.26
21755	326	123801	71.08	174.39
21764	327	025438	70.99	174.23
21771	327	154139	70.94	174.36
21772	327	172612	71.17	174.76
21773	327	191044	70.92	174.57
21777	327	223014	71.15	174.68
21792	328	214845	71.69	176.14

# RAW BUOY DATA

BUOY #432

ORBIT	JULIAN DATE	TIME HHMMSS	LAT.	LONG.
21804	329	225358	71.76	175.78
21830	331	212959	72.04	175.62
21857	333	201117	72.05	175.06
21865	334	155939	72.02	175.17
21865	334	155939	72.02	175.17

## RAW BUOY DATA

BUOY #443

ORBIT	JULIAN DATE	TIME HHMMSS	LAT.	LONG.
20385	224	053522	70.11	134.11
20398	225	045342	70.37	135.49
20424	227	013928	70.42	135.58
20425	227	051808	70.47	135.73
20427	227	085023	70.48	135.62
20453	229	054025	70.53	135.66
20457	229	143032	70.63	135.64
20466	230	050054	70.75	135.98
20495	232	085423	71.11	136.56
20499	232	155646	71.19	136.58
20514	233	184619	71.34	136.59
20519	234	054425	71.32	136.43
20531	235	031503	71.26	136.01
20537	235	120822	71.19	136.33
20546	236	060644	71.17	136.50
20548	236	094003	71.25	137.08
20552	236	164122	71.25	136.27
20583	239	021156	71.56	136.55
20600	239	162618	71.67	137.03
20614	241	075725	71.67	136.86
20615	241	094405	71.67	136.87
20639	243	044624	71.67	136.94
20647	243	185422	71.73	137.34
20679	246	042704	71.76	137.80
20706	248	045027	71.59	138.19
20733	248	204609	71.54	138.28
20752	251	080526	71.60	138.75
20800	253	223855	70.94	139.09
20801	255	070428	71.30	139.61
20806	255	122323	71.20	138.40
20807	255	155747	71.06	138.52
20821	256	043609	71.14	138.95
20834	257	143326	71.20	139.35
20836	257	181206	71.32	140.11
20837	257	214421	71.30	140.16
20840	258	045725	71.38	140.33
20867	260	052256	71.68	141.17
20895	261	203453	71.66	140.72
20904	262	162307	71.73	140.87
20911	263	120810	71.83	140.99
20912	263	135345	71.84	141.08
20920	264	042200	71.90	141.13
20929	264	182855	72.05	141.40
21056	274	061444	72.73	145.28
21072	274	183915	72.83	145.41

## RAW BUOY DATA

BUOY #413

ORBIT	JULIAN DATE	TIME HHMMSS	LAT.	LONG.
21101	276	205023	72.95	147.25
21147	281	045535	72.98	151.17
21150	281	064215	72.95	151.22
21188	284	024522	73.01	152.82
21193	284	133041	72.95	152.43
21201	285	020136	72.87	152.29
21203	285	072800	72.85	152.01
21205	285	110120	72.89	153.84
21237	287	182606	72.21	155.27
21241	288	033213	72.16	155.28
21246	288	104205	72.08	155.42
21276	290	162322	71.61	155.66
21296	292	060752	71.68	158.04
21362	296	191912	71.94	160.10
21379	298	105438	71.83	161.29
21402	299	223420	71.50	163.05
21435	302	114025	71.12	166.18
21492	306	192314	70.68	169.04
21496	306	212242	70.70	169.11
21497	307	061913	70.76	169.17
21635	316	211704	71.51	168.59
21639	317	184951	71.47	168.44
21643	317	222311	71.47	168.40
21686	321	123620	71.63	169.05
21719	323	181632	71.04	170.13
21743	325	132413	70.57	170.75
21750	325	221317	70.56	170.86
21755	326	124236	70.39	170.99
21804	329	225656	70.76	170.67
21830	331	213030	70.90	170.78
21857	333	200820	70.73	170.50
21876	335	114555	70.70	171.47
21884	335	203042	70.77	171.80
21893	336	180849	70.84	172.46
21898	336	213441	70.88	172.41
22045	347	210129	71.33	168.90
22058	348	220944	71.35	168.74
22064	349	123903	71.27	168.17
22081	350	185638	71.30	167.94
22086	350	223206	71.31	167.89
22113	352	225533	71.07	167.93
22119	353	151029	70.91	168.03
22136	354	175549	70.81	168.09
22143	355	101357	70.81	168.04
22153	355	223517	70.86	168.04

## RAW BUOY DATA

BUOY #443

ORBIT	JULIAN DATE	TIME HHMMSS	LAT.	LONG.
22158	356	130541	70.86	168.06
22172	356	215029	70.89	168.09
22267	363	221607	70.39	170.00
22269	364	194751	70.38	169.71
22281	365	172456	70.38	169.68
22313	367	230303	70.38	169.63
22317	368	100424	70.36	169.65
22326	368	222024	70.38	169.64
22337	369	213745	70.39	169.66
22346	370	135905	70.32	170.04
22364	371	220114	70.32	170.31
22372	372	105019	70.37	170.31
22375	372	175243	70.44	170.21
22381	372	230827	70.45	170.03
22394	373	222443	70.45	169.67
22407	374	233051	70.41	169.61
22412	375	121644	70.41	169.76
22417	375	173228	70.40	169.74
22424	376	094932	70.38	169.81
22470	379	195941	69.96	169.83
22492	381	113822	69.69	169.93
22496	381	183839	69.67	169.86
22500	381	220743	69.68	169.75
22506	382	105751	69.64	169.77
22514	382	175808	69.65	169.81
22523	383	190313	69.58	169.88
22535	384	145441	69.54	170.16
22537	384	182346	69.57	170.16
22545	385	122418	69.61	169.74
22551	385	141058	69.72	170.07
22560	386	133027	69.76	170.13
22571	386	151707	69.74	170.17
22581	387	213028	69.64	169.94
22613	389	215253	69.76	169.28
22627	391	133029	69.93	169.38
22684	395	193204	70.04	168.99
22688	395	230316	70.05	168.95
22747	400	123251	69.25	169.50
22751	400	193515	69.19	169.69
22768	401	152332	69.02	169.85
22844	407	181833	69.08	170.21

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